How Emission Systems Will Affect Harvesting Equipment

Wisconsin Custom Operators Annual Meeting
January 26th, 2012

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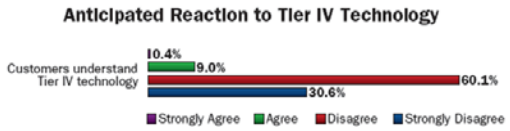
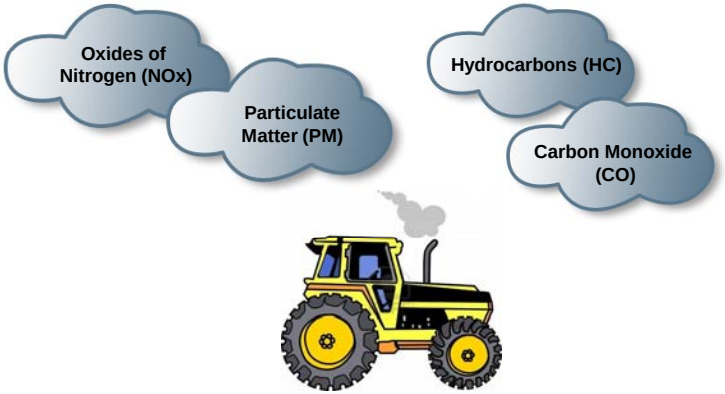
University of Wisconsin – Madison

Why Were Here



Regulated Diesel Emissions



Consequences of Diesel Emissions

Emission	Environmental Impact	Health Impact
PM	Smog	Respiratory diseases, cancer.
NOx	Smog, ozone	Respiratory diseases.
HC	Ozone, GHG	Eye and lung irritation.
CO	Ozone, GHG	Heart, circulatory, system failure.

Emission Regulations

Causes of HC and CO

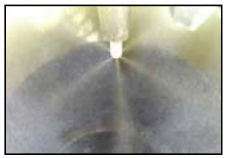
✓ HC and CO created by:

- Incomplete combustion - poor fuel-air mixing
- Unburned fuel - cylinder crevices
- Burned oil - worn engine parts

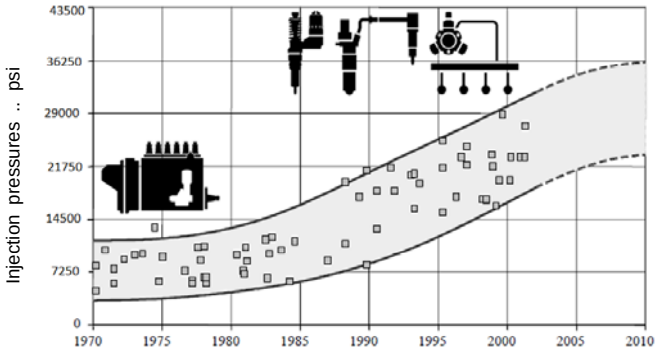
Eliminating HC and CO

✓ Better air-fuel mixing.

- New piston shapes – more "swirl"
- High injection pressures
- Multiple injection events
- More but smaller injector holes



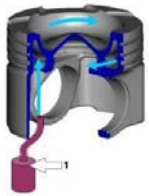
Diesel Injection Pressures

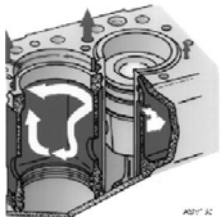


After Bahr (2002)

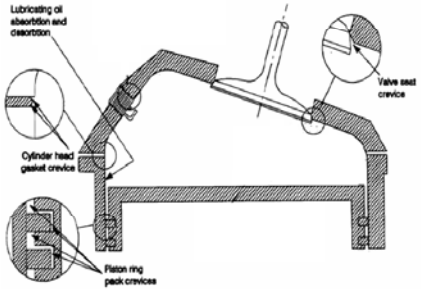
Eliminating HC and CO

- ✓ Reduce oil consumption, which reduces PM
  - Valve stem seals – added or improved
  - Top-liner cooling and top-piston lubrication (reduces wear at piston turnaround)



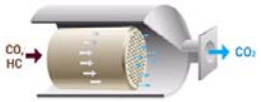


Eliminating HC and CO



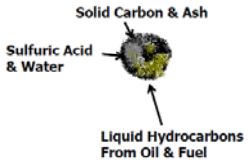
Eliminating HC and CO

- ✓ Not possible to eliminate all HC and CO, so Diesel Oxidation Catalyst (DOC) is used.
- ✓ Needs no maintenance or regeneration.



Particulate Matter – PM

- ✓ Three components to PM:
  - "Dry" PM - carbon and ash
  - "Wet" PM - unburned fuel condensed on "Dry" PM
  - Sulfates – from fuel sulfur



Particulate Matter – PM

- ✓ PM caused by :
  - Over fueling
  - Worn injectors
  - Low injection pressures
  - Late injection timing

Nitrous Oxides – NOx

- ✓ NOx – formed during high temperature combustion.

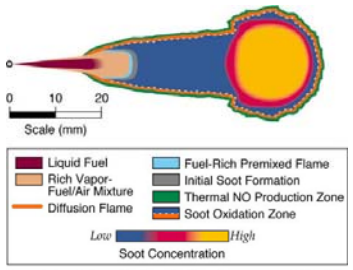
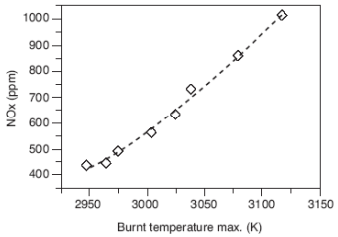


Figure 1. Quasi-steady Diesel combustion plume as presented by DEC (1997). Courtesy Dr. John E. Dec (Sandia National Laboratories).

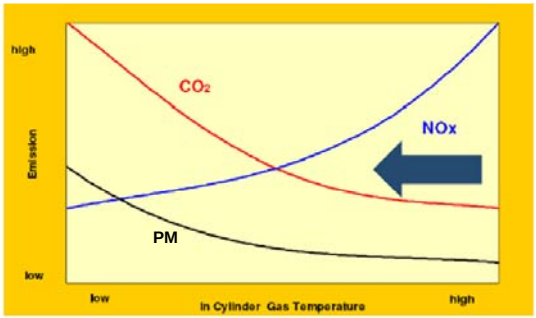
Nitrous Oxides – NOx

- ✓ NOx can increase exponentially at high combustion temperatures.



Diesel Dilemma

- ✓ In-cylinder reduction of NOx increases PM production :



Technologies for NOx and PM Reductions

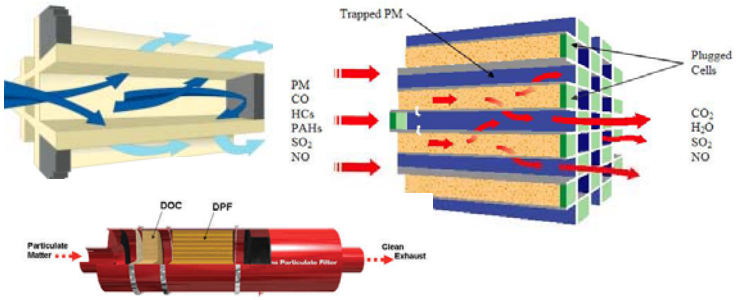
- ✓ In cylinder solutions:
  - NOx - Exhaust gas recirculation (EGR);
  - PM - Charge air management to provide excess oxygen
- ✓ After-treatments:
  - With EGR - diesel particulate filters (DPF);
  - Without EGR - selective catalytic reduction (SCR);
  - Both EGR and SCR need diesel oxidation catalyst (DOC).

EGR Systems

- ✓ During certain engine conditions, EGR valve opens and exhaust gas routed back to intake manifold.
- ✓ Exhaust gas cooled by engine coolant prior to recirculation.
- ✓ Process reduces oxygen level, reducing combustion temperature by several 100° F.

Diesel Particulate Filter (DPF)

- ✓ PM trapped porous media with adjacent channels plugged at opposite ends, forcing the exhaust gas through the porous wall.

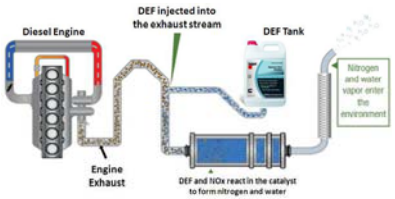


DPF Regeneration

- ✓ When soot loading reaches about 45%, back pressure sensor will indicate to ECU regeneration is required.
- ✓ PM "burned off" by increasing exhaust temperature:
  - Retarded injection
  - A fuel injector/burner in the exhaust
- ✓ Sulfur harms catalyst and increases regen temperature.
- ✓ Ash must be periodically removed – either by washing/cleaning or exchange of DPF.

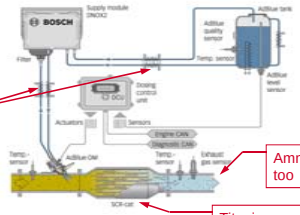
Selective Catalytic Reduction (SCR)

- ✓ SCR uses urea which converts to ammonia from exhaust heat.
- ✓ NH_3 reacts with NOx over a catalyst to form N gas and H_2O.



Selective Catalytic Reduction (SCR)

- ✓ Urea injection rate must be controlled.
- ✓ If rate is too high, not all the NH_3 will react with the NOx, and some NH_3 will "slip" through the catalyst.



DEF must be at proper temperature and shouldn't hard freeze.

Ammonia "slip" when NH_3 too much or T_{ex} too low.

Titanium, precious metals.

Diesel Emissions Fluid (DEF)

- ✓ What happens when DEF freezes?
  - EPA requires DEF flow within ~ 1h.
- ✓ What happens when DEF runs out?
  - Power derated such that operator will be so annoyed that refill will occur.

Pros and Cons - SCR

….it my equipment and my money and if I want to void the warranty what business is it of yours? …removing the SCR crap and voiding the warranty is a moot point. When did it become immoral to modify equipment I own?

ATTENTION: *The fuel system, exhaust after-treatment system, and engine on your machine are designed and built to government emissions standards. Tampering by dealers, customers, operators, and users is strictly prohibited by law. Failure to comply could result in government fines, rework charges, invalid warranty, legal action, and possible confiscation of the machine until rework to original condition is completed. Engine service and/or repairs must be done by a certified technician only!*

Pros and Cons - SCR

- ✓ Pros:
  - Combustion optimized for power and efficiency
  - 1 – 5% less fuel consumption
  - No DPF w/ some systems
- ✓ Cons:
  - DEF use probably will offset fuel savings
  - Complicated metering system
  - Power derate w/o fluid

Pros and Cons - EGR

- ✓ Pros:
  - No additional fluids required
  - No additional operator inputs required
- ✓ Cons:
  - Slightly greater specific fuel use
  - Exhaust most be cooled by coolant
  - DPF requires regeneration – small added fuel use

NTT Comparison

POWER TAKE OFF PERFORMANCE

Power HP (kW)	Crankshaft Speed rpm	Diesel Consumption Gal/hr (l/h)	Lb/hp-hr (Kg/kW-hr)	Hp-hr/gal kW-hr/l	D.E.F. Consumption Gal/hr (l/hr)
MAXIMUM POWER AND FUEL CONSUMPTION					
Rated Engine Speed – (PTO Speed – 1051 RPM)					
303.55 (226.35)	2000	16.06 (60.80)	0.370 (0.225)	18.90 (3.72)	1.10 (4.15)
Standard Power Take Off Speed (1000 RPM)					
335.05 (249.85)	1801	16.97 (64.25)	0.354 (0.216)	19.74 (3.89)	1.10 (4.15)
Maximum Power (1 hour)					
335.05 (249.85)	1801	16.97 (64.25)	0.354 (0.216)	19.74 (3.89)	1.10 (4.15)

SCR Tractor

Dates of tests: November 12 -22, 2010

POWER TAKE-OFF PERFORMANCE

Power HP (kW)	Crank shaft speed rpm	Gal/hr (l/h)	lb/hp-hr (kg/kW-h)	Hp-hr/gal (kW-h/l)	Mean Atmospheric Conditions
MAXIMUM POWER AND FUEL CONSUMPTION					
Rated Engine Speed—(PTO speed—1048 rpm)					
300.60 (224.63)	2000	16.54 (61.83)	0.376 (0.229)	18.76 (3.70)	
Standard Power Take-off Speed(1000 rpm)					
351.41 (242.11)	2004	17.49 (66.19)	0.372 (0.226)	18.95 (3.73)	
Maximum Power (1 hour)					
350.73 (233.34)	1800	17.77 (67.28)	0.369 (0.225)	19.11 (3.77)	

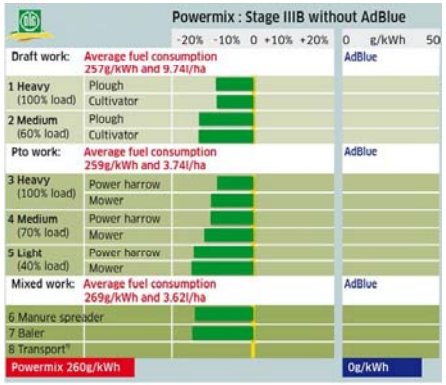
EGR/DPF Tractor

Dates of tests: April 6 -15, 2011

NTT Comparison

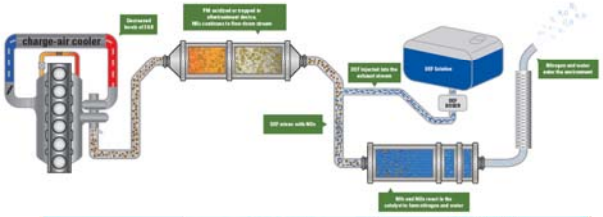
PTO Power (hp)	Fuel Use (gal/h)	DEF Use (gal/h)	Diesel SFC (hp-h/gal)	Diesel + DEF SFC (hp-h/gal)
SCR Tractor				
304	16.06	1.1	18.90	17.68
335	16.97	1.1	19.74	18.54
EGR + DPF Tractor				
307	16.34	0	18.76	18.76
331	17.77	0	18.95	18.95

Profi European Comparison



First, the current 'hot' talking point – fuel consumption. At rated speed the supped 231g/kWh, this statistic dipping to 226g/kWh at maximum pto speed. In a nutshell these figures indicate that our test tractor did a top job of returning an economical performance while still managing to meet the required Stage IIIB legislation – and without the additional cost of a diesel exhaust fluid.

Meeting Tier 4 Final



Power range	EU Stage IIIB / EPA Tier 4 interim (2011)	EU Stage IV / EPA Tier 4 final (2014)
135 – 250 bhp 100 – 260 kW	4L, 6L **Series 900** SCR (up to 240 kW)	4L, 6L **Series 1000** EGR, SCR
375 – 430 bhp 280 – 320 kW	6L **Series 400** 6V **Series 500** SCR	6L **Series 1100** EGR, SCR
455 – 510 bhp 340 – 380 kW	6L **Series 400** SCR (up to 375 kW)	6L **Series 1300** EGR, SCR
535 – 620 bhp 400 – 460 kW	8V **Series 500** SCR (up to 480 kW)	6L **Series 1500** EGR, SCR
750 – 980 bhp 560 – 730 kW		10V, 12V **Series 1600** EGR, DOC

Harvester Changes

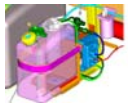
- Next generation harvesters will have:
  - ✓ More engine/exhaust components
  - ✓ Larger engine area and greater total weight
  - ✓ Higher engine area temperatures
  - ✓ Fewer places for chaff to build-up
  - ✓ Improved air flow

Harvester Changes

DPF Only

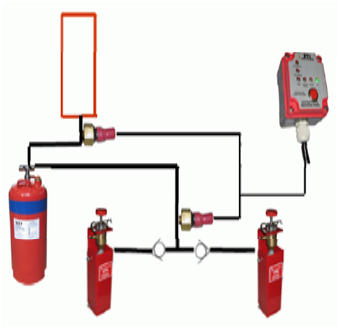
DPF + EGR Cooler

DPF + SCR + EGR Cooler



Harvester Changes

On-Board Fire Suppression Systems

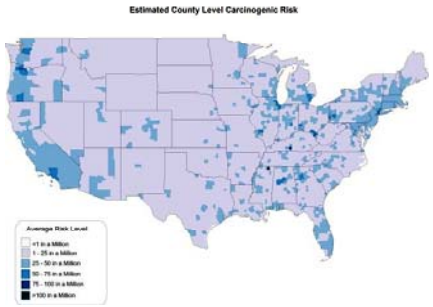


Will Retrofits Be Required

Summary of California Air Resources Board's
Statewide Truck and Bus Rule pertaining to Agricultural Vehicles
December 2008

Applicability –
This regulation applies to all trucks and buses operated within the state of California over 14,000 GVWR (does NOT include pick-ups or implements of husbandry such as tractors). It requires vehicles subject to this rule to comply with 2010 engine standards through replacement or retrofit by December 31, 2022. The engine must meet the 2010 engine standard depending on various factors including where the engine operates, annual mileage, number of vehicles and age.

Will Retrofits Be Required



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